WYLE LABORATORIES - RESEARCH STAFF

SUMMARY REPORT

FOR OCTOBER 1965 TO DECEMBER 1966

CONTRACT NO. NAS8-11308

Aerodynamic Noise Research Support

For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

ATTENTION PR-EC

January 12, 1967

The work performed under the contract can be defined as Aerodynamic Noise Research with special reference to the prediction of pressure fluctuations on large launch vehicles. During the work it became apparent that the lack of basic theoretical and experimental research results was causing difficulties in developing reliable prediction techniques for Saturn launch vehicles. Work performed during the current period has therefore concentrated on establishing the necessary foundation for improved environmental predictions.

The scope of work for the present contract is as follows:

a) Develop and perform appropriate wind tunnel experiments designed to obtain that information which is lacking for the development of reliable prediction techniques for Saturn I B vehicle noise environments.

b) Perform theoretical investigations of the turbulent shock wave interaction phenomena associated with regions of flow in vehicle interstage areas.

c) Perform a theoretical investigation of the degree of influence exerted by an oscillating shock wave on the spectrum of pressure in the separated region immediately behind the shock as would occur in the compression corners of vehicle interstage areas.

d) Perform theoretical and experimental investigations of shock wave instability at cone-cylinder junctions as opposed to cylinder-cone junctions, as in C.

In order to provide rapid transmission of results to Marshall Space Flight Center staff, reports have been issued as tasks on the contract have been competed. The following reports were submitted during the period October 1965 - December 1966.

Prediction of the Inflight Fluctuating Pressures on Space Vehicles, Wyle Research Report, WR 65-26, December 1965.

The Acoustic Environment due to Separated Flow and Oscillating Shocks, Wyle Research Report, WR 66-8, March 1966.

Flow Visualization Experiments with Separated Supersonic Flow, Wyle Research Report, WR 66-23, Arpil 1966.

The Fluctuating Pressures due to Shock Interactions with Turbulence and Sound, WR 66-35, June 1966.

Each of these reports contributes in some way to each of the tasks set out in the above scope of work. A short summary of each of these reports is given below.

Wyle Report 65-26 gives methods for the prediction of fluctuating pressures on space vehicles based on currently available results. Part of the work discussed was performed during the previous contract period. The sources studied included attached boundary layer turbulence, separated flow turbulence, oscillating shock waves, protuberance flows, jet impingement, cavity response phenomena, and base pressure fluctuations. Emphasis was placed on separated flow and oscillating shock phenomena. Typical levels for each source were given as a function of vehicle Mach number, geometry, and total head. Frequency spectra and correlation areas were also given where possible.

Wyle Report 66-8 analyzed in detail the available information on the problem of surface pressure fluctuations produced by separated flow and oscillating shocks. Three classes of supersonic separated flow were recognized, each of which could be approximated by a constant separation angle of about 12.5 degrees. The effect of Reynolds number was discussed and it was shown that test Reynolds numbers greater than 5×10^6 were required for good comparison to the full scale case. Data from several sources was used to define typical fluctuating pressures for both transonic and supersonic separated flows.

Wyle Report 66-23 reports the results of experiments on supersonic separated flow in the Marshall Space Flight Center, seven inch wind tunnel. Shadowgraph and surface flow visualization experiments were performed with the object of defining the geometry and flow mechanisms of the separated regions. The results generally supported previous analyses of the flow. It was found that the reattachment process was unsteady, and this would be expected to lead the substantial fluctuating surface loading on the flare. The mean position of the reattachment point was also found to be a function of flare angle.

Wyle Report 66-35 presented a theoretical analysis of the pressure fluctuations caused by the interaction of turbulence with a shock. It was found that the near field fluctuation levels were very high, of the order of 164 dB for a typical flight case. It therefore appears that shock turbulence interactions represent a significant source of fluctuating loading on a space vehicle. The interactions between sound and shock was also studied. It was found that sound waves passing through a shock were magnified typically by about 4.5 dB, and this effect appears to explain the sensitivity of an oscillating shock to wind tunnel noise.

Additional work during the contract period has included detailed study of the unsteady mechanisms within the supersonic separated flow. Unfortunately, this work has not yet been completed, because of problems in scheduling at the Marshall Space Flight Center, and currently because the wind tunnel has been dismantled for cleaning. It is recommended that the required data be analyzed when they become available from Marshall Space Flight Center. Experiments on a subsonic separated flow at Wyle Laboratories have been completed, and substantially analyzed. However, no report has been issued on this task, since it was felt that further analysis and comparison with theory was required. Theoretical work on both supersonic separated flows and on the pressure fluctuations in attached and separated boundary layers was also performed. Although some success was achieved with each of these studies, it was not thought that the results obtained were of sufficient significance to justify a report at this time.

The results obtained during the present contract period have provided much theoretical and experimental information which can be used to develop reliable prediction techniques for Saturn launch vehicles. In particular, the theoretical results of WR 66-35 have demonstrated the potential significance of shock-turbulence interaction as a new source of intense surface pressure fluctuation.

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